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Japanese Published Unexamined Patent Application (A) No. 02-214020, published August 27, 1990; Application Filing No. 01-32931, filed February 13, 1989; Inventor(s): Teruhisa Yokozawa et al.; Assignee: Fuji Electric Corporation; Japanese Title: Magnetic Recording Medium Manufacturing Method

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## MAGNETIC RECORDING MEDIUM MANUFACTURING METHOD

### CLAIM(S)

A method to manufacture a magnetic recording medium having a carbon protective layer on its magnetic layer, characterized in that after the carbon protective layer is formed, it is set aside for a specific period of time until the contact angle of purified water contacting with said surface reaches 60° or higher and, subsequently, a burnishing process is applied to the surface of said carbon protective layer.

### DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a method to manufacture a magnetic recording medium having an excellent lubricity characteristic.

(Prior Art)

In recent years, a medium having a ferromagnetic alloy thin film for its magnetic layer has come to be a focus of attention as a high recording density magnetic recording medium (hereinafter simply referred to as a medium). Such a medium generally has a carbon protective layer on the magnetic layer surface to protect the magnetic layer from an external atmospheric air to prevent deterioration of the magnetic layer. More specifically, a carbon protective layer having excellent lubricity is formed by forming a carbon film with a thickness of a few hundreds / on the magnetic layer by sputtering and by removing the fine bumps by burnishing the carbon layer surface.

The lubricity of such a carbon protective layer is known for its being enormously controlled by the surface condition of the magnetic layer which is its backing layer, for example, the surface roughness. Therefore, a variety of engineering are done to the magnetic layer surface in the manufacturing process of the medium to create an ideal surface condition. For example, there is a well-known manufacturing method, wherein a texture process is applied to the substrate surface of the medium, and the magnetic layer is formed on this substrate surface to create the required surface condition.

(Problems of the Prior Art to Be Addressed)

However, even when the surface of the magnetic layer is formed into an ideal condition, the lubricity performance of the carbon protective layer formed on the magnetic layer can be irregular, producing an irregular lubricity characteristic of the medium.

The present invention, to solve the aforementioned problem, attempts to present a medium manufacturing method that can form a carbon protective layer having lesser irregularity in lubricity performance and can manufacture a medium having a uniformly excellent lubricity characteristic.

(Means to Solve the Problem)

The aforementioned objective is accomplished by a method to manufacture a magnetic recording medium having a carbon protective layer on the magnetic layer, wherein after the carbon protective layer is formed, purified water is left on the surface for a specific time period so that its contact angle will become 60° or larger, and subsequently, a burnishing process is applied to said carbon protective layer surface.

Fig. 1 shows a partial sectional view of the carbon protective layer of the medium, on which purified water was dripped. The purified water dripped on the surface of the carbon protective layer on the magnetic layer 1

forms a flat dew, contacting with the carbon protection surface at a contact angle  $\theta$ .

The contact angle  $\theta$  at which the purified water 3 contacts with the surface of the carbon protective layer 2 becomes 60E or larger when the medium on which the carbon protection film has been formed is left in an atmosphere at a normal temperature and at normal humidity for 12 hours or longer. The long hours after which the contact angle  $\theta$  becomes 60E or larger can be shortened by blasting an air to the carbon protective layer surface. By blasting the air at speed 0.5 m/second or higher for 2 hours or longer, the contact angle  $\theta$  can be made 60E or larger. A higher humidity atmosphere can also shorten said time. If the carbon protection surface is left in the atmosphere with relative humidity 70% or higher for 2 hours, the contact angle  $\theta$  can reach 60E or larger.

(Operation)

There are many unclear aspects about the lubricity performance of the carbon layer. At least it is known that lubricity performance of the carbon layer is extremely poor in a vacuum but gets much better when it is left in an atmospheric air for a long time. It is recognized from an empirical fact that this is because of the hard layer of hydrocarbon formed on the outermost

surface of the carbon layer. More specifically, when said medium is left in an atmospheric air, the hard layer made of hydrocarbon is gradually formed on the outermost surface of the carbon layer and grows into an excellent cover layer with a thickness of some tens / [T. Note: “Some tens” is an expression unique with Japanese, and means any number between 20 – 90], demonstrating an excellent lubricity characteristic.

In the manufacturing process of the medium, fine bumps are eliminated from the surface of the carbon protective layer and a burnishing process is applied to the surface in the final step so that a magnetic head can travel smoothly on it. The inventors of the present invention found that the lubricity characteristic of the manufactured medium dramatically changes depending upon the time length during which it is set aside after formation of the carbon protective layer before the burnishing process. It is presumed based on the empirical facts that if a burnishing process is applied while the formation of the hardened layer of hydrocarbon is incomplete on the carbon protective layer surface, the hydrocarbon layer on the surface is scraped, insufficiently covering the carbon protective layer surface and reducing the lubricity performance, and that if a burnishing process is applied to the surface after the hardened layer of hydrocarbon has completely been formed, the hydrocarbon layer can sufficiently cover the carbon protective

layer surface even after the fine bumps on the surface are scraped and removed, so an excellent lubricity characteristic can be produced.

The inventors of the present invention further found that how far the hardened layer of hydrocarbon has been formed can be judged by the contact angle of the purified water on its surface, and that by burnishing said surface after the hardened layer of hydrocarbon has been formed enough for said contact angle to reach  $60^\circ$ , the fine bumps on the surface can be removed, and an excellent lubricity characteristic can be produced.

When the contact angle reached the angle larger than  $60^\circ$ , the hardened layer of hydrocarbon is presumed to have been formed by 80% or more.

Also, it became clear that if the burnishing is applied to the surface while the formation of the hardened layer of hydrocarbon is incomplete, the hardened layer of hydrocarbon, even if it is set aside in an atmospheric air, cannot be highly lubricant.

(Embodiment Example)

Fig. 2 shows a linear graph indicating the relationship between the contact angle of the purified water and the time period during which the carbon protective layer is left in an atmospheric air after its formation by sputtering before the burnishing process is applied. The relationship between said time period and the contact angle varies depending upon the

condition under which the carbon protective layer is set aside. In Fig. 2, the bold line indicates when the carbon protective layer was left under a normal temperature and normal humidity, the broken line when left under a high temperature and relative humidity 70%, and the dotted line when the air was blasted to it at speed 0.5 m/second at a normal temperature and normal humidity.

As is shown in Fig. 2, the contact angle of the purified water on the surface is  $30^\circ$  immediately after the carbon protective layer has been formed by sputtering. But while this is left in an atmospheric air, the formation of the hardened layer of hydrocarbon progresses as time passes, and the contact angle grows larger. Once the hardened layer of hydrocarbon completely has covered the carbon layer surface and has a thickness of some tens / after having been left in an atmospheric air for a long time, its formation comes to a stop, and at this time, the contact angle of purified water is approximately  $70^\circ$ . The hardened layer has been formed nearly by 80% when the contact angle of purified water reached  $60^\circ$ . If a burnishing process is applied when the hardened layer of hydrocarbon has reached  $60^\circ$ , in other words, after the hardened layer of hydrocarbon has been formed 80% or higher, the fine bumps on the carbon protective layer surface can be



removed and the surface can be completely covered with the hardened layer of hydrocarbon, so the medium excellent in lubricity characteristic can be produced. The carbon layer has to be left in an atmospheric air for 12 hours or more at a normal temperature and normal humidity to get the contact angle 60° or larger, but it takes only 2 hours if the 0.5 m/second speed air is blasted to the carbon layer surface in a relatively humidity 70% atmosphere or even at a normal temperature and normal humidity, so the time period can be shortened to approximately 1/6. Accordingly, a high humidity atmosphere accelerates the formation of the hardened layer of hydrocarbon, but formation of a dew on the surface is not preferable. The relative humidity 70% - 80% without generation of the dew is most ideal. Blasting an air is also effective, and in such a case, the air speed is preferably 0.5 m/second – 2 m/second. The longer time period is preferred for the time period during which the carbon layer is left in an atmospheric air for formation of the hardened layer of hydrocarbon, but the shorter time period is preferable in terms of manufacturing. It will be practical to leave it in an atmospheric air for 12 hours – 1 week in case of a normal temperature and normal humidity, and 2 hours – 6 hours in case of blasting an air to the surface of the carbon layer at a normal temperature and normal humidity.

(Embodiment Example 1)

On the substrate surface, in which an Ni-P layer is formed on a disk-shaped Al alloy sheet by electroless plating, a Cr backing layer, co-Ni alloy magnetic layer, and a carbon protective layer were successively formed.

This medium was left in a normal temperature and normal humidity atmospheric air for 48 hours. Subsequently, a final burnishing process was applied to its surface. More specifically, while the medium is being rotated at 500 rpm, a WA#8000 polishing tape was pressed against the carbon protective layer surface at flow rate 30 nl/minute; this tape was fed, while contacting with the medium, in the reverse direction to the rotating direction of the medium, and was reciprocated 5 times at 300 mm/minute speed in the radial direction of the medium to perform the burnishing.

The lubricity performance of the medium thus manufactured was measured by a sliding contact test. This is an abrasion test, in which the medium is rotated at low speed at which the magnetic head, on which is exerted vertical load (approximately 10 gf), does not float. Also, changes in the friction coefficient were measured while sliding the magnetic head against the medium surface. As a result, after 60 minutes of friction, the friction coefficient was 0.5 or less, as shown in Fig. 3, which demonstrates

an excellent lubricity characteristic. In Fig. 3, the range of changes in the friction coefficient is roughly indicated by 2 lines.

As to the surface roughness of the medium, average roughness  $R_a$  was 60 / in the center line. The value obtained by subtracting the cut depth in the relative load length 1% from the cut depth in the relative load length 10% of the relative load curve on the surface,  $\in C_v(10\% - 1\%)$  value, was 130  $\Delta$ . In the profile of the surface, the roughness remained in the upper section, as shown in Fig. 4.

(Comparative Example)

The medium, in which layers were formed up to the carbon protective layer in the same manner as that in the Embodiment Example 1, was left in an atmospheric air at a normal temperature and normal humidity for 2 hours. Subsequently, this medium was put to a burnishing process in the same manner as that in the Embodiment Example 1. The lubricity of the medium thus manufactured was measured in the same manner as that in the Embodiment Example 1. The result is shown in Fig. 5. As is evident from Fig.1, the friction coefficient exceeded 1.0 after nearly 20 hours of friction, which demonstrates a poor lubricity characteristic. In comparison with this example, it is obvious that the lubricity characteristic of the Embodiment Example 1 is dramatically improved. The range of changes in the friction

coefficient is roughly indicated by 2 lines. The surface roughness  $R_a$  of the medium in the comparative example was  $55 \mu m$ , and  $C_v(10\%-1\%)$  was  $90 \mu m$ . The profile of the surface showed lesser roughness in the upper section relative to that shown in Fig. 4, which indicates that the upper section was scraped.

#### (Embodiment Example 2)

In the same manner as in Embodiment Example 1, the medium on which the layers were formed up to the carbon layer was left in the environment of a normal temperature and normal humidity while blasting the  $0.5 \text{ m/second}$  air to its surface for 4 hours. Subsequently, a burnishing process was applied to its surface in the same manner as that in Embodiment Example 1.

The result of examining the lubricity of this medium is shown in Fig. 7. The range of changes in the friction coefficient is roughly indicated by 2 lines. In spite that the medium was left in said environment only for 4 hours, the friction coefficient demonstrated a low value of 0.8 after 60 minutes of friction, which obviously indicates an excellent lubricity characteristic.

#### (Embodiment Example 3)

The medium on which the layers were formed up to the carbon layer in the same manner as in Embodiment Example 1 was left in the high

humidity atmosphere of 80% relative humidity and of 33E C temperature for 4 hours. Subsequently, a burnishing process was applied to the surface in the same manner as that in Embodiment Example 1. The result of examining the lubricity characteristic of the medium is shown in Fig. 8. The range of changes in the friction coefficient is roughly indicated by 2 lines. In spite that the medium was left in said atmosphere only for 4 hours, the friction coefficient was as low as 0.7 after 60 minutes of friction, which indicates an excellent lubricity characteristic.

(Advantage)

In the manufacturing method of a magnetic recording medium having a carbon protective layer on its magnetic layer of the present invention, after the carbon protective layer is formed, it is set aside for a specific time period until the contact angle of purified water contacting with the surface reaches 60E or higher, and subsequently, this carbon protective layer surface is put to a burnishing process. When said contact angle reaches 60E or higher, the hardened layer made of hydrocarbon is presumed to have been formed 80% or more on the carbon protective layer surface. When the burnished process is applied to this surface, fine bumps are removed from the surface, and the carbon protective layer free from irregularity and having an excellent lubricity characteristic, for its being completely covered with the hardened

layer of hydrocarbon, can be manufactured. Therefore, a recording medium free from irregularity and having an excellent lubricity characteristic can be manufactured.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a partial sectional view of the carbon protective layer on which purified water was dripped. Fig. 2 shows a linear graph indicating the relationship between the contact angle of the purified water on the surface and the time period between the carbon protective layer formation and the burning process applied to its surface. Fig. 3 shows a linear graph indicating the result of measuring the changes in the friction coefficient of the medium produced by applying a burnishing process to the carbon protective layer surface after it was left in a normal temperature and normal humidity atmosphere for 48 hours. Fig. 4 shows a profile of the medium surface produced by applying a burnishing process to the carbon protective layer surface after it was left in a normal temperature and normal humidity atmosphere for 48 hours. Fig. 5 shows a linear graph indicating the result of measuring the changes in the friction coefficient of the medium produced by applying a burnishing process to the carbon protective layer surface after it was left in a normal temperature and normal humidity for 2 hours. Fig. 6 shows a profile of the surface of the medium produced by applying a

burnishing process to the carbon protection surface after it was left in a normal temperature and normal humidity for 2 hours. Fig. 7 shows a linear graph indicating the result of measuring the changes in the friction coefficient of the medium produced by applying a burnishing process to the carbon protective layer surface after it was left in a normal temperature and normal humidity environment while blasting the 0.5 m/second air. Fig. 8 shows a linear graph indicating the result of measuring the changes in the friction coefficient of the medium produced by applying a burnishing process to the carbon protective layer surface after it was left in the high humidity atmosphere of 80% relative humidity and 33E C temperature for 4 hours.

1. Magnetic layer
2. Carbon protective layer
3. Purified water

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Figure 4 illustrates an embodiment of an apparatus using rollers for applying the resist transfer pad loaded with photoresist to the slider surface.

# Detailed Description of the Invention and the Preferred Embodiments

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Figure 2 illustrates that layer structure of a resist transfer pad 30 according to the invention. The transfer layer 31 is selected to be smooth, nonreactive and to have low adhesion to the photoresist. The preferred material for the transfer layer 31 is polydimethylsiloxane (PDMS). *(Alternatives)* The thickness of the PDMS layer is selected to be thin enough to not excessively deform when pressed against the slider surface. A typical range might be from 10 to 100 microns. Under the transfer layer 31 is a cushion layer 32 which is designed to provide flexible support so that the resist transfer pad will tend to conform to the large scale topography of the target surface and smooth out local irregularities. One consequence of excessive local conformation is "rolloff" which is excessive thinning at the edges. Thus, the hardness of the cushioning layer 32 can be selected according to the specific application, i.e., the nonplanarity of the surface of the slider and the desired tradeoff between conformity for long range topography and smooth local irregularities. The cushion layer 32 is preferably silicone rubber, but other rubber alternatives can be used. The material for the cushion layer is selected to be compatible with PDMS and its curing agent. The curing agent is typically supplied by the manufacturer. One commercially available curing agent contains a proprietary platinum-based catalyst that catalyzes the addition of the SiH bond across the vinyl groups, forming Si-CH<sub>2</sub>-CH<sub>2</sub>-Si linkages. PDMS is cured by an organometallic crosslinking reaction. The resistance of the cushion layer material to the curing agent must be determined empirically. The thickness of the preferred silicone rubber cushion layer is preferably from 1 to 3 mm. Optionally a stiffener layer 33 can be included which can be a higher modulus material such as Mylar,

Figure 3 illustrates an embodiment of the loaded resist transfer pad 37 with photoresist 34. The photoresist 34 can be applied to resist transfer pad 30 by a conventional means such as a spin-stand used to rotate the resist transfer pad 30 while liquid photoresist is applied and allowed to spin out to a consistent, thin level. <sup>positive tone</sup> Liquid photoresist is preferred to avoid the ledging problems associated with <sup>negative tone</sup> dry resist. The

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This stiffener layer assists in keeping the transfer pad flat during resist spinning and pad transport, but its primary function is to provide appropriate overall pad stiffness.

*Other polymers may be used, although the slow surface energy of PDMS is particularly useful in facilitating resist transfer.*

*although for other kinds of parts having different planarity or topography thicker or thinner pads may be appropriate.*

invention aids in the use of liquid photoresist on the nonplanar surface of the sliders which is well known weakness of liquid photoresist. After the photoresist is applied to resist transfer pad an appropriate curing process such as storing the loaded resist transfer pad in a small volume closed container for selected period of time.

5 The loaded resist transfer pad 38 can be applied to the surface of a slider by conventional means including manually although an automated means is deemed preferable. Figure 4 illustrates an embodiment of an apparatus 40 using rollers to apply the loaded resist transfer pad 38 to the slider 20 surface. For mechanical stability, etc. the sliders 20 are preferably ~~supported by carriers or~~ *mounted in carriers and transported by* pallets 41 which are transported by a conventional conveyor system 49. Support roller 48 is positioned under the conveyor 49 to provide a rigid position for the slider as it passes under the roller with the loaded resist transfer pad 38. The loaded resist transfer pads 38 are held by a cover-tape 37 which is fed from reel 42. The loaded resist transfer pad 38 is pressed against the slider surface by roller 43 as the pallet moves on the conveyor 49. A section of cover-tape 37 is cut by prior art (not shown) and adheres to and moves with the pallet as it clears the roller 43. The pallet 41 with a section of cover-tape 37 and the loaded resist transfer pad 38 continues forward with the slider 20 and pallet 41. The cover-tape 37 and the resist transfer pad 30 must be removed from the slider 20 before lithography processing. The resist transfer pad 30 can be removed by any conventional means including manual means. The photoresist 34 remains on the slider surface when the resist transfer pad is removed. *Trapped*

An alternative embodiment uses piston laminator to press the loaded resist transfer pad onto the surface of the transducer. Preferably the piston laminator operates in a vacuum chamber to help reduce bubbles in the photoresist. The loaded resist transfer pad is placed on the press plate which is then pressed against the slider surface. In this embodiment as well the resist transfer pad is lifted off and the photoresist remains on the transducer.

Conventionally multiple applications of photoresist are required to fabricate a complete set of features on an air-bearing surface. The resist transfer pads of the invention can be used for some or all of these steps. The invention can be used with a 30 any etching technique for which photoresist can be used as a mask including deep ion milling.

Except where express materials, thickness values, etc., have been given above, the layers, structures and materials embodying the invention are according to the prior art and are fabricated according to the prior art.

5 The compositions given herein have been described without regard to small amounts of impurities that are inevitably present in practical embodiments as is well known to those skilled in the art.

10 Although the embodiments of the invention have been described in a particular embodiment, the invention as described herein is not limited to this application and various changes and modifications will be apparent to those skilled in the art which will be within the scope of the invention.